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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

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UNIVERSITY OF HAWAII
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN NO. 71

CITRUS CULTURE IN HAWAII

By
W. T. POPE, Senior Horticulturist

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HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

(Under the joint supervision of the University of Hawaii, and the Office of Experiment Stations, United States Department of Agriculture.)

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[1] Appointment effective April 1, 1934.
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INTRODUCTION

Citrus fruits of various kinds have been in cultivation in Hawaii for more than a hundred years. The production of citrus for export reached its peak during the period 1840-70. During part of that time oranges were a leading product of export in the Kona District on the island of Hawaii (*22*)[1]. Since 1870, localities on the larger islands of the Hawaiian Archipelago have become well known for their citrus culture. Citrus growing in Hawaii has greatly diminished, however, as a result of the development of the more remunerative sugar, coffee, and livestock industries. About 1910 the Mediterranean fruit fly (*Ceratitis capitata*) began to menace the industry, and the locally produced supply of citrus fruit is not now equal to the demands of the rapidly increasing population. During the fiscal year ended June 30, 1932, the value of the citrus fruits imported into the Territory of Hawaii increased to $485,908.

Citrus investigations have been in progress at the Hawaii Agricultural Experiment Station since 1904, and the results have

[1] Italic numbers in parentheses refer to Literature Cited, pp. 36, 37.

been published in the annual reports and in bulletins (*16; 21*) of the station. The experimental orchard contains 238 trees, representing 40 different species and varieties (fig. 1), and it has been of value in furnishing data concerning the cultural requirements and propagation of the trees, and insect and plant-disease control. It has also been a source of propagating material for cooperative experiments in various parts of the Territory. This bulletin has been prepared to meet the demand for general information regarding the culture of citrus fruits under Hawaiian conditions.

BOTANICAL RELATION

Botanically the genus Citrus belongs to the family *Rutaceae*. The term "citrus" was in ancient times applied to a fragrant African wood (*3, v. 2, p. 780*), but Linnaeus used it as the generic name of the citron and related species. From about a dozen species of citrus many varieties have been developed.

KINDS OF CITRUS AT THE STATION

The more important kinds of citrus at the station are the following:

Sweet oranges (*Citrus sinensis*): Hawaiian, Valencia, Mediterranean Sweet, Navelencia, St. Michael, and Ruby, and Washington Navel, Thompson Navel, and Buckeye Navel; sour oranges (*C. aurantium*): Seville or Bigarade; acid limes (*C. aurantifolia*): Kusaie, Rangpur, West Indian, and Tahiti; sour lemons (*C. limonia*): Eureka, Villafranca, Lisbon, Sicily, Rough, Ponderosa, and American Wonder; pomelos (*C. decumana, C. grandis, C. maxima*): Victoria, Quintal, Gehring, Carter, and Siamese; shaddocks: Bitter, Tantalus, and Pyriform, or Chinese, and Kohala; grapefruits (*C. paradisi*) (*4, p. 156*): Triumph, Duncan, Marsh, Imperial, Foster, Royal, Pernambuco, Tresca, and Woodworth; mandarins (*C. nobilis*): Dancy, Satsuma, Willow-leaved, King, Cleopatra, and Clementine; Chinese orange or calamondin (*C. mitis*); citron (*C. medica*); kumquat (*C. japonica*); trifoliate orange (*C. trifoliata or Poncirus trifoliata*); cabuyao (*C. hystrix*); tangelo (citrus hybrid types); and tabog (*Chaetospermum glutinosa*).

The last eight varieties mentioned in the above list have not proven as yet of sufficient importance in the experiments at the Hawaii Station to warrant giving varietal descriptions in this bulletin.

PROPAGATION

For more than a century, Hawaiian oranges, limes, lemons, and pomelos[1] were propagated almost entirely from seed in Hawaii. The careful selection of seed from trees of desirable quality gave comparatively good results, but no true varieties could be established without employing vegetative methods of propagation. Inarching, layering, and the rooting of cuttings have not been used to any considerable extent because of certain

[1] The term "pomelos" includes both the grapefruit and shaddock types.

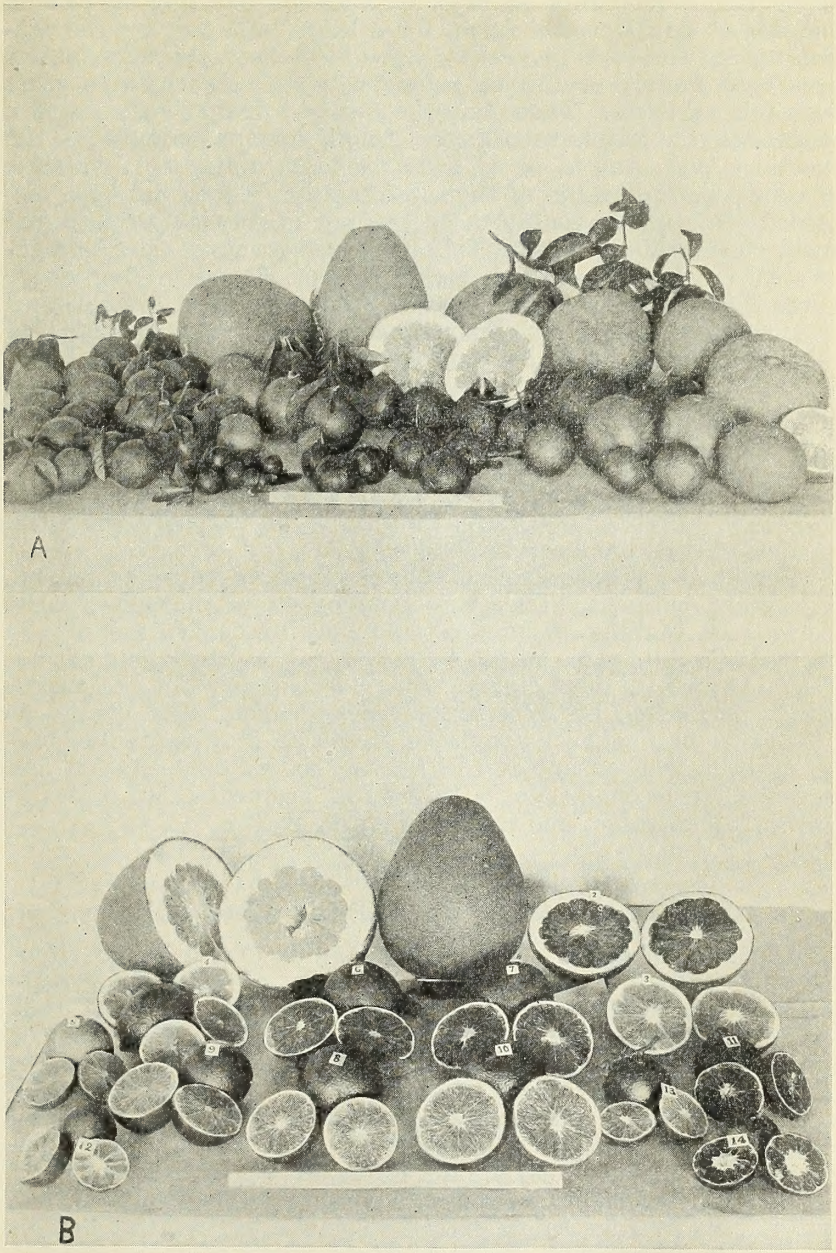

Figure 1.—Citrus fruits grown by the Hawaii station: A, twenty-five varieties; B, fruits which usually are seedless, or nearly so, including pomelo, grapefruit, orange, lemon, mandarin, and lime.

disadvantages associated with them. Experiments in vegetative propagation, including several methods of grafting, of which budding is considered a form, have been employed by the station during the past 10 years. Since 1906, seed propagation has been used mainly to develop rootstock plants on which to graft desirable varieties. These have been grown from sweet oranges, sour oranges, trifoliate oranges, rough lemons, pomelo of the shaddock type, and tabog (*Chaetospermum glutinosa*), which is of a different genus but of the same family. Tabog has been discarded for use as a rootstock on account of its slow growth and hard, close-grained wood. Trifoliate orange stock does not appear to have any material advantage for Hawaii. The use of rough lemon and sweet orange stock has also been discontinued because of a lack of resistance to gummosis. Sour orange and shaddock stocks have been proved best, especially the latter because of its great vigor, adaptability to grafting, and apparent disease-resistant qualities. Several kinds of citrus trees that were grafted on shaddock stock in 1921 reached bearing age in 1926. They have not transmitted any unsatisfactory characters. The Cleopatra mandarin, which was highly recommended by the late E. N. Reasoner of Oneco, Florida, as an excellent rootstock for most citrus, has been introduced.

Vegetative propagation of citrus requires considerable accuracy and patience. The work includes the production of rootstocks, the making of unions, and careful cultivation of the grafted plants to sizes suitable for planting in permanent places. It is a branch of horticulture which is usually, but not necessarily, performed by experienced nurserymen. The details of vegetative propagation adaptable to citrus in Hawaii have recently been worked out at the Hawaii Experiment Station and published in *Circular* No. 6, "Grafting Tropical Fruit Trees in Hawaii," illustrated, and issued in April, 1933.

CULTURAL REQUIREMENTS

Temperature, Moisture, Soil, and Windbreaks

The general requirements for all kinds of cultivated citrus are practically the same. In many parts of Hawaii requisite conditions of temperature, moisture, and soil for all species and varieties of citrus are found, but in some places protection is needed against strong winds. The most suitable growing places range from near sea level to about 1,000 feet. In these belts leeward slopes are preferable. In Hawaii the maximum temperature seldom ranges above 85° F., and the minimum temperature, at sea level, never falls below 50° F. In most parts of the agricultural belt the average annual temperature is 74°, with a daily average range of 11°. The average relative humidity is about 72 per cent. Here moisture exerts the most marked influence on citrus. Citrus may be grown with a rainfall ranging from 50 to 150 inches per year. This amount is large as compared with that required by other orchard crops, but it should be remembered that the heavy foliage, which has no marked rest period, transpires large amounts of water. However, in

very humid localities where the rainfall is 100 inches or more per year, a lichen (*Physcia stellaris*) may be found growing upon the trunk and the branches of citrus trees, and the juice of the fruit becomes insipid. In hot, dry localities where irrigation is necessary, transpiration is rapid, the lichen does not appear, and the fruit contains less juice but it is of better flavor. Under such conditions the amount of moisture consumed still remains high.

The moisture requirements of a citrus orchard are best learned by studying the condition of the trees. They should never be allowed to show symptoms of suffering, such as drooping leaves. In such a condition both tree and fruit are likely to be injured. Citrus will thrive on many kinds of soils, but the soil should be at least 4 or 5 feet deep, rich, abundantly moist, and well drained. Extremely heavy or very loose soils are not suitable for citrus culture.

In windy localities young citrus trees should be given temporary protection during the winter. This may be supplied in the form of a piece of burlap about a yard square tacked to three upright stakes on the windward side of the tree. As a protection against the heavy winds that come from the northeast and occasionally from the south, large permanent windbreaks should be grown where needed. Such rapidly-growing, wind-resistant trees as the eucalyptus (*Eucalyptus robusta*), Australian oak (*Grevillea robusta*), mango (*Mangifera indica*), and ironwood, or so-called Australian pine (*Casuarina equisetifolia*) will serve the purpose. They may be set alternately in three rows 10 feet apart, and the same distance apart in the row. The eucalyptus should be set nearest to the prevailing wind; and the row adjoining the orchard should consist of ironwood and mango trees set alternately in the row; and the central row should be made up entirely of the grevillea trees. The mango has a strong, dense top and, if properly grafted, has the additional value of producing fruit in season. When the mango trees begin to crowd, some of the grevillea and possibly some of the ironwood trees may be removed. The horizontal roots of these trees can be prevented from encroaching on the citrus area by maintaining a narrow ditch 3 or 4 feet in depth about 4 feet from the row of ironwood trees. Preventing the spread of roots on one side does not have any serious effect upon the ironwood trees. The ditch should be dug out every other year, left open for a few months, and then refilled.

Planting

The most suitable time for setting young citrus trees is in the early spring, but the late spring may be preferred in cool localities, particularly where the rainy season is in the summer. At some of the lower elevations, where the summers are very hot and dry, citrus trees are not set until the fall. The orchard site should be cleared and the land thoroughly and deeply plowed. The surface should be cleared of all vegetation, stones,

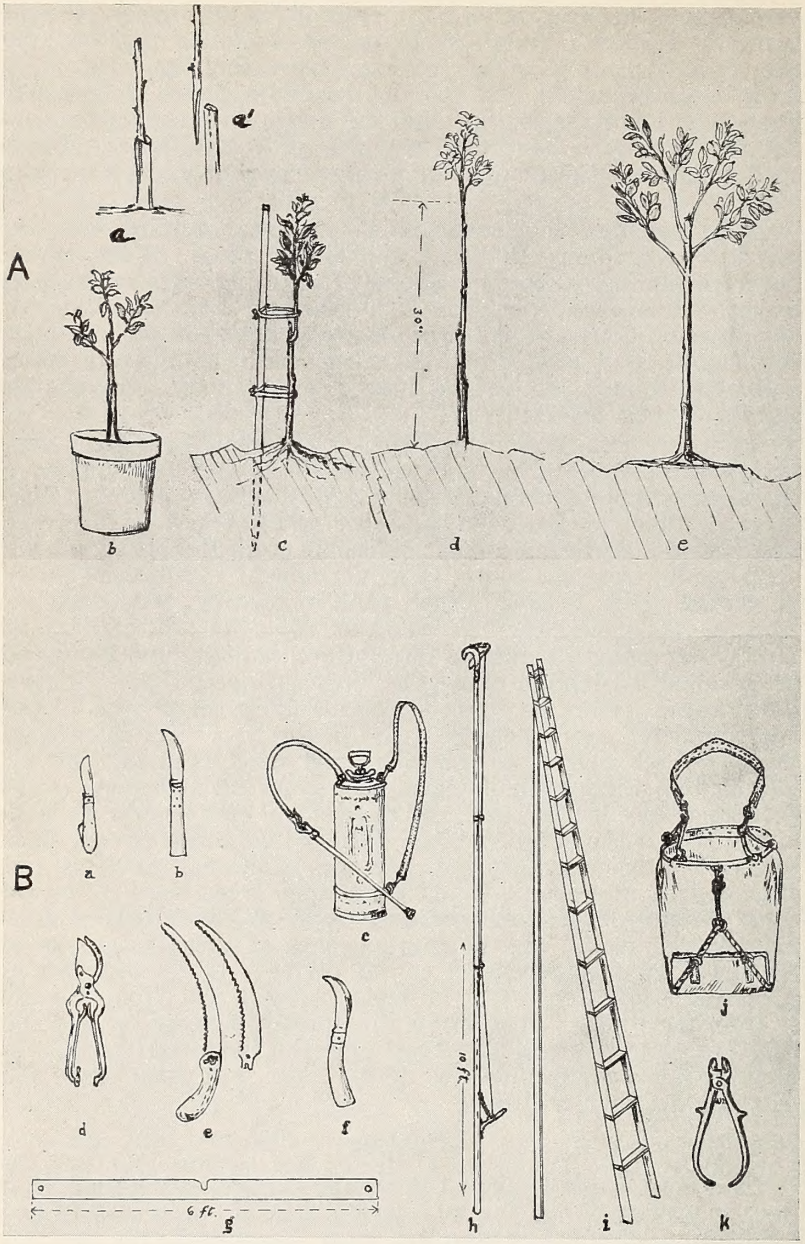

Figure 2.—Early shaping of, and necessary equipment for, citrus trees. A, **a**. a', Bark graft; **b**, pot-grown grafted tree ready for planting; **c**, first-year training in orchard; **d**, height for forming crown; **e**, four well-arranged crown branches. B, **a** and **b**, Grafting knives; **c**, air-compression sprayer; **d**, pruning shears; **e**, and **f**, pruning saw and knife; **g**, planting board; **h**, long-handled pruner; **i**, pruning and picking ladder; **j**, picking sack; **k**, clippers.

and undesirable trash, then broken up, and harrowed. The rows should be staked out and the holes for planting dug.

There are several ways of arranging citrus trees in rows. The most important of these are the square, triangle, hexagonal, and quincunx. These methods are described in popular horticultural books. Trees occupying considerable areas of hilly land may be set along contour lines to facilitate irrigation and cultivation. Large areas may be laid out with the help of a surveyor's transit, and medium and small areas with a strong wire cable. This is measured at desirable intervals by knobs soldered to it for each tree row. The wire is stretched across the orchard and a stake is set at each place to be occupied by a tree. Some kinds of citrus require more space than others, because of their ultimate size; hence, different distances apart in orchard planting are recommended. Mandarin and lime trees require areas 20 feet across; oranges, grapefruit, and pomelo, 22 to 24 feet; and lemons and shaddocks, 25 to 28 feet.

When the orchard site is comparatively level the trees may be planted on the square. They should be set in straight rows at right angles. In an orange orchard, for example, the trees are set 22 by 22 feet each way, which permits the growing of 90 trees to the acre.[2] Under this arrangement the trees will not become crowded for 40 or 50 years, and they will make profitable yields during this time. In planting the trees 22 by 22 feet each way, the first row should be laid out as a base, parallel with, and at a distance of about 11 feet from, one of the straight boundary lines. Along this row the spaces should be measured off and the stakes set 22 feet apart. From these stakes the cross rows are laid out at right angles to the base, stakes being set 22 feet apart along each row. When the holes are dug the stakes should be removed and a planting board (fig. 2, B, *g*) should be used to indicate the exact place the tree is to occupy. This is made of 1-inch board about 5 inches wide and 6 feet long. A 1½-inch hole is bored about 4 inches from each end and exactly midway between these two holes and on the edge of the board a notch is cut. This board is placed on the ground with the tree stake in the central notch. Then a wooden pin about 1 foot long is firmly driven into the ground in the holes near the ends of the board. The board next is raised, and the projecting pins are left in the ground until after the tree is planted. Before the tree stake is removed the size of the hole about it should be roughly marked out.

The tree holes, preferably square, should be at least 3 feet across and 2 feet deep. Surface soil containing some sand and enriched with well-decomposed barnyard manure should be placed in the bottom of the holes before the trees are set. A considerable amount of coarse sand should be mixed with heavy soil. Coral sand from the seashore is suitable for the purpose, because it contains calcium. Each tree is removed from the

[2] To find the number of trees required to set an acre, multiply the two distances in feet at which the trees stand apart, and divide the product into 43,560 (square feet in an acre). The quotient will be the number of trees required.

container at the time of planting, care being taken to avoid disturbing the soil about the roots. The young trees should be set firmly by lightly tramping the soil as the holes are filled. The natural ground line of the tree should be an inch or two above the natural surface of the orchard (fig. 2, A, *c*), particularly in heavy soil. High planting is believed to prevent several forms of gum diseases that affect citrus trees. In Puerto Rico, Henricksen (*15, p. 21, 33*) found that the planting of citrus trees on mounds effectively safeguarded them from foot rot, a gum disease doing considerable damage to citrus trees planted too deep.

Immediately after they are planted, the trees should be liberally watered. Temporary shading is not necessary if the planting is well done and the trees were exposed to the sun during their last month in the nursery. A vigorous, vegetative growth should be maintained during the first few years to enable the trees to produce good crops.

Tillage

The best results are obtained with the tillage necessary to produce spring and fall cover crops. Turning the cover crop under in early spring has been satisfactorily practiced at the station. If the herbage is high it should be cut finely with the disk and turned under to a depth of 6 or 8 inches with the plow. A few days later the plowed field should be disked to pulverize the surface, and the seed either drilled in, or broadcast and harrowed. Weeds should be destroyed.

Irrigation

In most parts of Hawaii occasional prolonged drought may injure the growth of orchard crops. There are also good citrus-growing localities where irrigation is necessary every spring and summer. The windward slopes of the islands usually are favored with an adequate rainfall, but the warm leeward slopes where irrigation is possible afford the best results with citrus. Irrigation is generally applied in shallow basins about the base of each tree trunk. The method is not satisfactorily used on heavy soils. They soon become "water-logged," a condition favorable to the development of gum diseases. Under this method on heavy soils much of the water is lost by deep percolation and soluble plant food is carried below the root zone. Citrus trees should not be set too low in the ground and the basins should be leveled at the beginning of the second year and a moat provided 1 or 2 feet from each tree for the irrigation water. The moat should be maintained from year to year above the feeding roots.

The irrigation water may be conducted to the highest point of the orchard through concrete or iron pipes, or, on comparatively heavy soil, through open ditches, preferably of stone, concrete, or wood (*12. p. 4-20*). From the highest point the water may be delivered to the moat of each tree through temporary furrows made between tree rows with a furrower. The grade of the furrows should be less than 10 percent so that the water will flow gently and not wash the fine soil to lower levels. The short ditches connecting the furrows with the moats may be

made with a hand shovel or with a hoe, and the amount of water for each tree may be regulated by filling the short ditch with several shovelfuls of soil to form a gate.

Some growers who have water under pressure are satisfied with a pipe system. According to the pressure the system may be constructed of 1-, 1½-, or 2-inch galvanized iron pipe laid at a depth of 15 inches and arranged to give one upright with faucet for each 9 trees. A hose is used to carry the water from faucet to any of the 9 moats. Overhead irrigation is described by Coit (*7, p. 198-199*), but it has been seldom practiced in Hawaii. Thomas (*27, p. 353*) found that California growers generally "followed certain arbitrary rules, especially in regard to the frequency of application and the amount of water applied." In his opinion, irrigation furrows that exceed 250 or 300 feet in length are undesirable. The amount of water required for good growth depends on temperature, humidity, rainfall, the nature of the soil, and the age of the trees.

Intercropping

A short-time crop should be kept growing between the trees as a source of revenue or as a green manure. Such short-time crops as peas, beans, carrots, beets, tomatoes, sweet potatoes, and upland taro are best adapted to the lower elevations during the winter and the early spring. The roselle, poha, cabbage, and other plants adapted to the lower temperatures also may be used at elevations above 800 feet. Such perennials as papayas and alfalfas are sometimes grown. A single row of passion fruit (*Passiflora edulis*), midway between orchard rows of citrus, is being grown at the Kona substation, at an elevation of 1,500 feet. Intercropping in the young citrus orchard should be discontinued at the end of five years so that it will not interfere with the development of the trees. Intercropping should not be practiced on heavy soils with plants requiring frequent watering.

Cover Crops

Cover crops for green manuring greatly benefit Hawaiian soils, many of which are deficient in organic matter. The cover crop when turned under returns to the soil all the fertilizing elements that were removed in the making of the crop and adds humus or organic matter which greatly improves the texture and the moisture-holding capacity of the soil. According to Piper and Pieters (*20, p. 5*), soils vary greatly in their water-holding capacity, and the addition of humus affects both the physical and the chemical properties of the soil. They state that 100 pounds of sand can hold only 25 pounds of water and 100 pounds of clay 50 pounds, whereas the same weight of humus will hold 190 pounds. Humus increases the water-holding capacity of the soil and makes it workable. Humus is also helpful in the formation of bacteria which make available great stores of inert plant food in the soil. Leguminous cover crops aid in increasing the nitrogen content of the soil. In most localities cover crops are maintained during the season of heavy rainfall

to prevent surface washing. Cover crops that are planted during the dry season, unless irrigation is practiced, will hardly reach usable size before the heavy rains begin.

The crop should be started in the early fall so that the ground will be well covered by the first of December. There should be sufficient moisture for both the cover crop and the orchard trees, and the cover crop may be plowed under as soon as its herbage is ample. The entire plant should be plowed under before the seeds mature sufficiently to germinate. A cover crop should be turned under from 2 to 6 weeks before another crop is planted. Piper and Pieters (*20, p. 21*) found that "green manures do not increase soil acidity, or, if so, that such a condition is transitory." Deep-rooted cover crops should be planted on hard subsoils that form a plow-sole. The cheese weed (*Malva rotundifolia; M. parviflora*) usually yields an abundance of herbage, and the large, penetrating roots, when severed by the plow, decay and leave deep drainage canals. Among the green-manure crops used as cover crops at the station are mungo beans (*Phaseolus mungo*), sunn hemp (*Crotalaria juncea*), cowpeas (*Vigna catjang*), and velvet beans (*Stizolobium aterrimum; S. deeringianum*).

The mungo bean attained a desirable size in 3½ months and apparently made a fair green manure. The small seeds were planted with the drill in rows 2 feet apart at the rate of 20 pounds per acre.

Sunn hemp and several other Crotalarias commonly grown in Hawaii as green manures stand among the highest in the production of nitrogen, as is shown by Johnson, Thompson, and Sahr (*19, p. 5, 8*). The seeds were planted with the drill in rows 3 feet apart at the rate of 15 to 20 pounds per acre.

The cowpea produced ample herbage in less than 5 months. For green manure the seeds were planted 2 to the hill, forming rows 2 feet apart each way. This arrangement requires about 8 pounds of seed per acre. When drilled in rows 2 feet apart, 10 to 12 pounds of cowpea seed are required per acre. Hume (*18, p. 290*) states that cowpeas cannot be recommended for all soils in Florida because of the presence of "a nematode worm." He also states that so far as known this nematode does not attack orange roots.

For several years the Black Mauritius variety of velvet bean has been used for green manure in the station citrus orchard. This variety makes strong vine growth. The seed may be drilled in rows 3 or 4 feet apart, or it may be planted at the rate of 3 or 4 to each hill.

Fertilizing

The addition of a complete fertilizer to the soil in which citrus is growing has been proved beneficial at the station. The necessary elements of plant food are nitrogen, phosphorus, potash, and calcium. Standard complete commercial fertilizers for citrus trees may be purchased on the market and contain about 5 percent of nitrogen, 6 to 8 percent of phosphorus, and 2 to 3 percent potash. There is some calcium in the compounds carrying the

two latter elements. Lava soils have sufficient calcium for most plants. For desired plant growth often nitrogen has to be added in the form of nitrate of soda, or as a superphosphate of ammonia. The former is quicker in its action than the latter. Organic nitrogen may also be added to the soil in the form of dried blood, tankage, or other plant and animal material. Barnyard manure is a complete fertilizer and is usually rich in nitrogen. Less nitrogen and more potash in the complete fertilizer is recommended to improve maturing citrus fruits, the nitrogen being reduced from 5 to 3 percent, and the potash increased from 3 to 5 percent.

In a young experimental citrus orchard in Kona, fertilizer is being applied according to the plan of Vosbury and Robinson (*29, p. 27*). In Hawaii the time of application may vary with the most active growing season in different localities. For example, on the island of Hawaii the rainfall of the Hamakua (northeastern) coast is greatest in the winter, and in Kona, on the west side, it is greatest from April to November, while in Puna, on the southeast, it is comparatively uniform throughout the year. One-year-old grafted citrus trees, with roots washed clean of all soil to comply with the quarantine regulations, were planted early in the spring of 1931 in soil moderately incorporated with barnyard manure. In the summer of 1931, after new growth appeared, 1 pound of a complete fertilizer rather rich in nitrogen was applied to each tree. This was worked into the surface soil around the tree with a hoe and was followed by vigorous growth in the fall of 1931, when a second application was made. The third application, at the rate of 2 pounds to a tree, was made in April, 1932, at the beginning of the growing season, and a fourth application, at the rate of 2 pounds to a tree, was made in midsummer, 1932. Applications will be increased a pound to a tree until it begins to bear. Complete fertilizer will then be applied during the summer, but the nitrogen will be reduced to 2 percent. After the trees have borne for 10 years the amount of commercial fertilizer may be increased about a pound a year for the next 15 years. This amount of fertilizer and the plowing under of one or two green-manure crops should maintain soil fertility and orchard production.

Pruning

The citrus orchard should never be severely pruned. The tops should be cut back at the time the trees are planted to maintain a balance between the top and the roots that were pruned at the time of transplanting. The first 5 or 6 years should be devoted mostly to the production of a strong symmetrical tree. The branches forming the framework of the top should arise from the upper part of the trunk, be well-spaced and so shaped as to sustain heavy crops. The foliage should shelter the framework but not be so dense in the interior as to exclude light and air. Severe pruning, with the lemon in particular, may lead to a vigorous growth of water sprouts and resultant decreased yields. The object of pruning is to stimulate vegetative growth, remove undesirable branches, and increase the rate of growth

of the fruit. The crown or head, where the first, or framework, branches develop, should be 2 to 3 feet above the surface of the ground, depending on the frequency and severity of the winds to which the tree is exposed (fig. 2, A, *d*). The lower the crown, the less likely it is to be injured by strong winds, but a crown within 3 feet of the ground is suitable for orchard culture. At the end of a year the trunk should be headed back to about a foot above where the lowest branch of the crown is desired. All other growth than that intended for framework should be removed from time to time during the first season.

The young lateral branches forming the framework should be cut back to 8 to 10 inches to permit secondary branches to develop. These secondary branches are later thinned, leaving only two or three of the framework branches on the outside (fig. 2, A, *e*). Pruning should be done preferably following the gathering of the crop which, in most parts of Hawaii, is about midwinter. In the removal of large branches the under side should be cut about an inch deep ½ foot from the trunk. Then the limb should be cut on the upper side in front of the under cut to avoid danger of splitting the tree. The stub should be cut off close parallel to the trunk.

All cuts more than half an inch across should be covered with melted asphaltum paint or with melted grafting wax to prevent decay or the entrance of insects. Exposed parts of the trunk or of the branches should be liberally coated with whitewash to protect them from sun injury. Shamel, Pomeroy, and Caryl (*24, p. 31*) state that trees propagated from fruit-bearing wood secured from superior performance record parent trees of fruitful strains require little pruning under normal conditions.

The tools used in pruning citrus trees are simple and comparatively inexpensive and include a hand shears about 9 inches long, a saw, and a knife (fig. 2, B). The shears used at the station consists of a single blade and a guard (fig. 2, B. *d*). A small curved saw having a continuous series of teeth along one edge of the 12-inch or 14-inch blade (fig. 2 B. *e*) is used for large limbs. A 7-inch or 8-inch knife is used to smooth off surface wounds before they are painted (fig. 2, B, *f*). This knife should be large, strong, and sharp. A long-handled tree pruner may be used to remove small branches in the tops of tall trees (fig. 2, B. *h*). A strong, light ladder may be used for reaching parts of the tree not readily accessible from the ground (fig. 2, B. *i*).

INSECT ENEMIES

The Mediterranean Fruit Fly

The Mediterranean fruit fly (*Ceratitis capitata*) reached Hawaii from Australia in 1907 (*2, p. 9*), although it was not discovered here until 1910 (*2, p. 7*). Conditions in Hawaii are favorable to its rapid increase. The life cycle of this destructive pest is described by Ehrhorn (*9*). Government entomologists and others have done much to control the fruit fly through a study of its habits and the introduction of destructive parasitic

insect enemies (*1*). This work has been attended by success, as is shown by Willard (*30, p. 11*). Large quantities of citrus fruits are now produced in the Hawaiian Islands without infestation, but much fruit drops before it fully ripens as the result of punctures by the fruit fly.

Many growers have successfully ripened citrus fruit without infestation by bagging it. In a study of the best methods of protecting the fruit, the station used medium-weight brown-paper bags, and medium-weight cellophane bags to cover grapefruit, oranges, mandarins, and limes. Four-pound bags were used for grapefruit, three-pound bags for oranges, and two-pound bags for mandarins and for limes. The bags were put on when the fruit was still green and nearly full grown. The bag was placed about the fruit and tied tightly enough to prevent the entry of water in case of rain. A workman can place 50 to 150 bags per hour, depending on the convenience of reaching the fruit. No foliage should be bagged with the fruit. Although much rain fell during November and December, 1931, most of the bags were in good condition for from 30 to 50 days, when the fruit was picked. When the fruit ripened—those in the cellophane bags had deeper yellow coloring and possibly better flavor than the fruits in the paper bags.

Tree Cockroaches

Tree cockroaches (*Eleutheroda dytiscoides*) frequently girdle the bark of the twigs and eventually kill the trees. They are commonly found among dense clusters of foliage or fruits growing in bunches. This species differs from the common cockroach, the adults being smaller, of a darker brown color, with smoother wings.

Control—Tin cans containing a poisoned bait with openings only large enough to admit the pest should be tied among the twigs.

The Purple Scale

The purple scale (*Lepidosaphes beckii*) is a common insect enemy of the citrus species in Hawaii. It appears in great numbers on the bark, the leaves, and the fruit of the trees and produces honeydew which covers all parts of the plant. The honeydew forms a favorable medium for the growth of the injurious sooty mold (*Capnodium citri*). The adult female is purple colored, oyster-shaped, and about three-sixteenths inch long and one-sixteenth inch wide. The male is much smaller than the female and of yellowish color.

Control—This scale and the sooty mold may be controlled by sprayings with oil emulsion. Good spraying oil can be purchased in most markets, and, when emulsified with water, is ready for use. It is as effective as kerosene emulsion and can be more easily kept in stock. Directions for its use are furnished by the dealer. Kerosene emulsion is used by some growers. The best kerosene emulsion is prepared according to the following formula:

KEROSENE EMULSION

Laundry soap	½ pound
Water	1 gallon
Kerosene (coal oil)	2 gallons

The soap should be thoroughly dissolved in water while it is boiling over a fire. The solution should be removed to a safe distance from the fire and the kerosene slowly added to it. The mixture should be agitated with a force pump sprayer, using a direct discharge nozzle throwing a one-eighth inch stream. The liquid is pumped back upon itself for 10 to 15 minutes. When completed, the emulsion should have the consistency of cream. The stock solution may be kept for several months and when used should be diluted with 8 to 15 parts of water, according to the nature of the insect to be sprayed. The compressed air knapsack sprayer may be satisfactorily used until the trees are several years old (fig. 2, B, *c*).

The Red Scale

The red or orange scale (*Chrysomphalus aurantii*) is circular and flat in form. The female varies from one-sixteenth to one-eighth inch in diameter, and has a transparent scale through which its red body shows. The male is smaller than the female and of gray or dark-brown color. The red scale is not so serious a pest as the purple scale. It appears on the stems, leaves, and fruit.

Control—The red scale is easily removed by spraying with oil emulsion.

The Florida Red Scale

The Florida red scale (*Chrysomphalus aonidum*), sometimes found on citrus foliage and fruit in Hawaii, is characterized by its circular, flat form, dark-brown color, and medial lighter dot. It has an average diameter of about one-twelfth inch, and appears in great numbers on the underside of the leaves and young branches. When seriously infested with it, the foliage turns yellow and occasionally a tree may die.

Control—The scale is controlled by spraying with oil emulsion.

The Green Coffee Scale

The green coffee scale (*Coccus viridis*) is soft and shieldlike, and of yellowish-green color with darker markings. It appears sometimes in great numbers on the leaves and stems of citrus trees and covers them with honeydew. A sooty mold sometimes develops in the honeydew and gives the trees a blackened appearance. The green coffee scale also attacks coffee trees in the Kona district, where it is partly held in check by introduced parasites and by fungus.

Control—Spraying with oil emulsion is recommended for control.

Other Scales

Other kinds of scale occasionally found on citrus trees include the chaff scale (*Parlatoria pergandi; P. ziziphus*), the red wax

scale (*Ceroplastes rubens*), and the cottony cushion scale (*Icerya purchasi*).

Mealybugs

Mealybugs (*Pseudococcus filamentosus*), and possibly other species) occasionally attack citrus trees, particularly young nursery stock, principally in dry weather. Most species of mealybugs are much alike in appearance, life history, and habits. The adult female varies from one-fourth to three-eighths inch in length, is about half as wide, and is covered with a white waxy excretion. The males are smaller than the females. All parts of the plant, including the roots, are attacked.

Control—Several special emulsions have been successfully tried at the station. Essig (*10, p. 128*) recommends a home-made emulsion with the following formula:

CARBOLIC ACID EMULSION

Water	40 gallons
Whale-oil soap	40 gallons
Crude carbolic acid	5 gallons

He states that the water should be brought to the boiling point in an iron kettle, the soap thoroughly dissolved in it and the crude carbolic acid added. The whole should be boiled for 10 or 15 minutes. The resulting mixture should be thick, light, creamy, and of milky white color. A smaller amount of this stock solution may be made by reducing the proportional parts. For use as a spray 20 gallons of water should be added to 1 gallon of stock solution. Spraying thoroughly once or twice a year, when growth is the least active, is recommended for mealybug control.

Aphis

The aphis or black fly (*Aphis* sp.) is not considered a serious pest of citrus in Hawaii, but nursery stock should be kept free from it by spraying. These pests usually are found in masses and suck the juice or sap from the tissues of the plant. They may be identified by the honeydew they excrete on most parts of the plant.

Control—Aphis, mites, and thrips may be controlled by spraying them with a mixture prepared according to the following formula:

NICOTINE-SULPHATE SOLUTION

Nicotine-sulphate (tobacco-leaf extract)	2 ounces
Whale-oil, or laundry soap	3 ounces
Water	4 gallons

The nicotine extract may be purchased in small quantities and kept stored until it is needed. For small, tender plants, the nicotine sulphate may be reduced to 1 ounce, and white soap substituted for laundry soap.

Orange Rust or Lemon Silver Mite

The orange rust or lemon silver mite (*Phyllocoptes oleivorus*) sometimes attacks citrus in Hawaii. It injures mainly the stems, foliage, and green fruit of orange trees, especially the fruit. The

mites are so small they are practically invisible to the naked eye. Both young and adults feed on the essential oils contained in the rind. The surface of the affected orange becomes scurfy and of a russet color, and that of the affected lemon silvery in appearance.

Control—Finely-powdered sulphur should be dusted on the infested parts with a blow-gun. Lime-sulphur spray is also recommended as a control measure. Spraying should be thoroughly done when the fruit is about half grown.

Other Insect Pests

The purple mite (*Tetranychus citri*) and red spiders (*T. sexmaculatus; Tennuipalpus irritans*) may be controlled by the methods recommended for the orange rust mite.

DISEASES

Citrus trees in Hawaii are attacked by a few serious diseases, caused mainly by fungi and occasionally by physiological disturbances. Many of the diseases are difficult to identify and some of them may exist for years before being observed.

Gummosis

Higgins (*16, p. 22*), in 1905, noted that gummosis or foot rot also commonly known in some other countries as *mal di gomma* (*Phytophthora parasitica; P. terrestris*), was "perhaps the most widespread of any citrus disease." Rhoads and De Busk (*23, p. 71*), who studied citrus diseases in Florida, state that gummosis "may be induced by various fungi, by chemical, mechanical, and insect injuries, and by certain physiological stimulations." The term "gummosis" is commonly applied to a number of diseases that cause gumming. The amount of gum exuded in each particular case is approximately proportional to the severity and extent of the disease. Pathological study has revealed certain distinguishing characters that identify this particular species from others. Thus, *mal di gomma* manifests itself when the citrus trees are of bearing age by the presence of drops of gum on the trunk near the ground. At first the inner bark and sapwood die, then larger areas become involved, the disease spreading upward to the basal portion of the main limbs and downward to the main crown roots. The dead bark gradually breaks away, leaving the dead sapwood exposed. *Mal di gomma* is often associated with *Pythiacystis gummosis*, which "derives its name from the causal agent, the citrus brown rot fungus (*Pythiacystis citrophthora*)" (*11, p. 125, 146*). Both diseases may be controlled by the same method.

Control—Gummosis can best be controlled by selecting a good orchard site having rich, well-drained soil, and ample water supply; using strong, clean, thrifty trees of standard varieties grafted on disease-resistant stock; and by properly setting the trees and maintaining them in vigorous condition. Particular attention is called to mound planting as an important method of preventing gummosis (*15, p. 24, 28, 33*). The young trees are

set on mounds the soil of which gradually wears away in a few years, leaving the crown roots exposed to the air. These roots are naturally more resistant than is the trunk to the soil fungi producing gummosis. As a further precaution the exposed parts of the roots and the lower part of the trunk should be treated with Bordeaux paste. Any depression about the base of the tree or the crown roots should be kept drained. Fawcett and Lee (*11, p. 140*) give several remarkable examples of the success of this treatment in California, and this method of combating gummosis is also reported to be successful in both Egypt and Palestine. When gummosis is discovered, the soil about the base of the trunk should be removed to expose the upper part of the crown roots. All diseased bark should be cut away and the entire trunk treated with Bordeaux paste (1 pound of bluestone and 2 pounds of unslaked lime with enough water to make a thick whitewash). On heavily fungus-infested soils this paste should be applied to the trunks of all the citrus trees, including the healthy ones, to safeguard them from gummosis. The treatment should be repeated every two years.

Psorosis or Scaly Bark

Psorosis is peculiar to the orange tree and is of limited occurrence in most citrus-growing countries. In some places it is confused with the general name of gummosis and is known as scaly bark or scaly bark gum disease. At the station the orange tree has been less severely attacked by this disease than by gummosis. The most conspicuous evidence of psorosis is the scaly character of the outer bark on the larger branches or the trunk of the affected tree. The scales are less than an inch across and curl up and drop, leaving the inner bark exposed. At certain seasons, or at certain stages of the disease, gum exudations may occur. Psorosis develops very slowly, and several years may pass before the foliage shows its effects. The leaves shrink, turn yellow, and are few in number, the twigs die back, and new shoots attempt to grow near the trunk. Five years or more may pass before the disease kills an orange tree. Smith and Smith (*25, p. 1135*) are of the opinion that scaly bark "apparently originates in an irregular moisture condition of the soil." They show that the disease has occurred in California "when irrigation by flooding was generally practiced and cultivation received little attention."

Treatment—Where only the branches are affected the tree may recover if the dead parts are cut off and the wounds are coated with thin Bordeaux paste. Where the trunk is only moderately affected the diseased portion should be cut out and the wounds treated with Bordeaux paste. Seriously affected trees cannot be saved and should be replaced. The disease is not contagious.

Verrucosis or Lemon Scab

Verrucosis or lemon scab (*Sporotrichum citri; Sphaceloma fawcettii*) occasionally attacks lemon fruits growing in moist localities in the Hawaiian Islands. Fawcett and Lee (*11, p. 485-*

496) give a comprehensive discussion of verrucosis. It is known to have been present in Japan from ancient times and in recent years has spread to many other parts of the world (*23, p. 33*). Verrucosis attacks the young leaves, twigs, and fruits of lemons, sour oranges, grapefruits, some mandarins, and certain other varieties of citrus. The outstanding characteristic of the disease is the formation of irregular, slightly raised corky lesions called "warts." These lesions are pinkish-colored at first, but darken with age, and the tops are covered with scab. The disease is most evident in moist weather. Its virulence varies from year to year, depending on climatic conditions, and nature of growth at the time of infection.

Control—Verrucosis can be controlled in Hawaii by thoroughly spraying the trees with Bordeaux mixture in late winter or early spring and when the fruit is forming. Bordeaux mixture is made of copper sulphate (bluestone), unslaked lime, and water in definite proportions. The 3-3-50 formula is generally considered to be of standard strength for controlling citrus diseases. To make convenient stock solutions, dissolve copper sulphate at the rate of 1 pound in each gallon of water in a wooden container. This is easily done by suspending the copper sulphate for about 12 hours in a sack in the top of the water. Slake the lime separately in a little water, then add more water to form a lime solution consisting of 1 pound of lime to each gallon of water. These two solutions may be stored separately for several months if they are covered tightly to prevent evaporation. For a 3-3-50 mixture, place 3 gallons of each solution in a wooden container and add 50 gallons of water while the agitator is running. The mixture should then be strained into the spraying tank and frequently agitated to prevent the settling of the precipitate formed by chemical union of the lime and the copper. Bordeaux mixture may be made destructive to insect pests following its use by the addition of 1 part of spraying oil at the time the mixture is poured into the spraying tank. This would give a formula of 3-3-50-1.

HARVESTING

The citrus crop should be handled with considerable care. Carelessness in this respect causes severe losses often after fine crops have been grown. The season of maturity of citrus fruits in Hawaii varies somewhat in different localities, but the main crop matures from midsummer to December. However, citrus of one kind or another may be found ripening in some locality during almost any month. Each fruit should be cut, not pulled, from the tree. The clippers should have, preferably, cup-shaped blades with rounded points (fig. 2, B, *k*). The stem should be cut close to the calyx or "button," which should be left on the fruit. The clipped fruit should be put into a cloth picking sack carried over the shoulder of the picker (fig. 2, B, *j*). Several types of picking sacks are in use. The improved type is adjustable in capacity, holding from 20 to 50 fruits, and opens at the bottom to keep the fruit from bruising when it is emptied into the field container.

Different types of picking ladders are used, but the kind having a third leg on hinges, which may be let down through the branches to rest on the ground, is considered the best (fig. 2, B, *i*). Care should be taken to avoid breaking young branches in moving the ladder about. The picked fruit should be carefully spread upon a sorting table in the packing shed. Fruit with abrasions or bruises should be culled. The sound fruit should be packed in small boxes for the market. The boxes should be of standard make and of such size as can be easily handled. In such containers the fruit will not be damaged by its own weight. Fruit that is to remain for several days in the boxes should be kept in a dry place having a free circulation of air. Citrus fruit, particularly oranges, may be artificially colored by some of the several gassing processes described by Barger and Hawkins (*5*). Their method of heightening the color of the fruit has not proved to be of sufficient importance for practice in Hawaii.

VARIETIES OF ORANGES

Hawaiian

The Hawaiian variety of orange has been in cultivation since its introduction by Captain Vancouver (*28, v. 1, p. 158*) in 1792. It grows better in some localities than in others and has been known on West Hawaii as the "Kona" orange, on the island of Oahu as the "Waialua" orange, and on the island of Kauai as the "Waimea" orange. Within recent years the name "Hawaiian" orange has come into general use (fig. 3). It has been propagated mainly from seed, and a natural selection has taken place. It is now propagated vegetatively from selected trees. Seedless fruits occasionally are observed, and fruits with a navel form of stigmatic portion are not uncommon. In most localities the season of maturity ranges from October to December. Like some other kinds of citrus trees, the Hawaiian orange is suitable to tub culture for ornamental purposes (fig. 3, B).

The tree is a tropical, broad-leaved evergreen with a roundish to upright top 20 to 30 feet high; the bark is grayish and thin; the young growth is more or less thorny; the foliage is dense, deep green; the leaves are of medium size; the blades are oval-oblong, roundish at base and pointed at apex; the margins are entire or slightly irregular; and the leafstalk is narrowly winged.

Fruit—Form, spherical, diameter, 3 to 3¼ inches; color, yellow to light orange; skin, thin and leathery with pebbled surface; flesh, dark yellow, juicy, subacid to very sweet and of mild flavor. The seeds, none to about 15.

Valencia

Several introductions of Valencia oranges have been made from California nurseries by private growers. From an introduction made by the station in 1906 five budded trees were set in the citrus orchard in 1909. The variety originated in the Azores, and reached America from an English nursery in 1870 (*7, p. 70*). Under favorable culture in California it has developed certain desirable characteristics as prolificacy, good keeping qualities, and lateness in maturing, becoming ripe when the navel varieties are out of season. In Hawaii the Valencia is in season from December to February, but has not as yet attracted much favorable attention.

The tree is of medium size, vigorous, and prolific; the thorns are few and small; the

Figure 3.—Hawaiian orange trees in fruit. A, young tree at the Hawaii Station. B, Tub-grown tree for ornamental and exhibit purposes.

foliage is typical of that of the sweet orange. The tree blossoms mainly in the early spring, but may blossom several times during the year.

Fruit—Form, more or less oblong, with somewhat depressed ring at stigmatic end; size, medium; color, pale orange; skin, smooth or slightly pebbled, thin, and tough; pulp, yellow, juicy, subacid; seeds, none to 5 or 6.

Mediterranean Sweet

The Mediterranean Sweet variety was introduced into Hawaii by the station in 1906, and budded on rough lemon stock. The plants were set in the citrus orchard in 1909 and proved to be thrifty and prolific. None of the trees has been attacked by gum disease. The fruit splits easily when the orchard has not been properly irrigated. The Mediterranean Sweet is a good orange but generally is considered inferior to the Hawaiian orange. Coit (*7, p. 71*) reports the Mediterranean Sweet as having been introduced into California from southern Europe through American and English nurserymen. The season in Honolulu is late summer and fall.

The tree is small; the leaves are narrow and numerous; and the small branches are almost thornless.

Fruit—Size, small to medium; form, spherical to oblate; color, deep orange; skin, of fine texture; juice, abundant and sweet; seeds, few and small.

Navelencia

The Navelencia originated in California, from where the Hawaii station obtained four grafted trees in 1906. These were on sour orange stock, but suffered considerably from gummosis, due to the poor soil in which they were growing and to deep planting. The variety has willowlike twigs and matures its fruit after the navel varieties have ripened, and before, or at the beginning of, the Valencia season. The Navelencia apparently is not as satisfactory for Hawaii as is the Valencia.

Fruit—Form, oblong; size, medium; flesh, smooth, firm, and thin-skinned; pulp, juicy, plentiful, and subacid; seeds, none to few.

St. Michael

The St. Michael (Paper Rind St. Michael) originated on the island of St. Michael, Azores, and was introduced into Hawaii by the station from Florida.

The trees are small, thorny, and prolific, and the fruit ripens about midwinter.

Fruit—Size, small; form, roundish to oblong; rind, firm, slightly pitted, and thin; flesh, coarse and yellow; acidity and sweetness are well blended in the juice; seeds, few.

Ruby

The Ruby was introduced into Hawaii by the station in 1906. The trees are prolific, medium in size, and almost thornless.

Fruit—Size, small; form, round; color, deep orange at full maturity; surface, pebbled; rind, firm; pulp sacs, small, juicy, and of pleasant flavor; seeds, about a dozen.

Sour (Seville or Bigarade)

The sour orange was introduced into Hawaii probably from Florida by private growers. It is a native of southern Asia. The seeds were obtained locally by the station.

The tree reaches a height of about 20 feet, is upright, and has a roundish top of dense foliage. It is a prolific bearer. The bark is smooth and free from disease. The fruit has only one use in Hawaii, the seeds being planted for seedling-stock production. This stock is very resistant to gummosis.

Fruit—Size, large; form, spherical to slightly oblate; very attractive pebbled surface of rich deep yellow; rind, thick; pulp, coarse and very sour. The flavor does not prove to be a substitute for lemon or for lime (fig. 4, A).

Figure 4.—Orange and grapefruit trees. A, Sour orange tree. It is resistant to gummosis and provides seed for rootstocks. B, The Pernambuco grapefruit was developed with a low crown for increased resistance to strong wind.

Washington Navel

The Washington Navel was introduced into Hawaii from California by private growers and by the station. About 1906 the station trees were grafted on sour orange, grapefruit, and sweet orange stock. Since then many trees have been propagated. With good culture the variety produces excellent fruit.

The trees are rather dwarfed and have few thorns.

Fruit—Form, roundish, slightly tapering at apex; diameter, 2½ to 3½ inches; color, yellow; surface, smooth to pebbled; rind, thin; juice, orange-colored, abundant, with acidity and sweetness well blended; seed, none to few.

Thompson Navel

The Thompson is a variety of navel orange and about 1891 was introduced to the trade by A. C. Thompson, of Duarte, California. It has been extensively grown in Hawaii, and has proved to be decidedly better than other navel varieties.

Fruit—Size, medium; rind, smooth and thin; pulp, yellow and of fine texture; juice, abundant and of good quality; seed, none to few.

Buckeye Navel

The Buckeye Navel is occasionally found in cultivation in Hawaii, but has no advantages over the Washington Navel or the Thompson. The trees of the three varieties are similar in form and in growth, but the fruit differs in shape, and the rind is thinner. The early fruit of the Buckeye often contains a number of spontaneous chimeras. As the ovary grows, ridges, usually reaching from the base to the stigmatic point, develop. Variation is not due to cross-pollination, and cannot be definitely established by vegetative propagation. Similar sectional chimeras occur in the Valencia orange and in the lemon.

Fruit—Size, medium; rind, smooth, thin, and tough; pulp, fine-grained; juice, of good flavor; normally seedless, but may become pollinated from other citrus and produce 1 to 15 seeds.

VARIETIES OF MANDARINS

Mandarin varieties are so different from other oranges as to be classified as a different species (*Citrus nobilis*). The Nobilis fruit is so called because of its quality. The trees are comparatively small, but vigorous and prolific; the branches have numerous slender twigs, and the leaf petioles are edged with very narrow wings; the flowers are small and white; the fruit usually is rough, has a distinctive aroma, and is of sweet and pleasing flavor. At maturity the rind is freely separated from the flesh. Hume (*18, p. 39*), who made a comprehensive study of citrus fruits, states that from the conclusions of De Candolle, mandarins may be considered as natives of Cochin China. A number of varieties are in cultivation in southeastern Asia, the East Indian Islands, and Japan. The species was introduced into Europe in 1805, and into Louisiana about 1850, whence it spread to Florida and to California.

The Hawaii station in 1906 introduced budded plants of the varieties Dancy, Satsuma, Willow-leaved, and King from California. Representatives of these are still growing in the station orchard and have been the basis of study of the varieties under Hawaiian conditions. Like most other citrus, the varietal characters are found mainly in the fruit.

Dancy

The Dancy has several synonymous names, as Tangerine, and Dancy's Tangerine.

Fruit—Form, oblate; greatest diameter, 2½ to 3 inches; color, deep yellow to orange; rind, glossy, somewhat pitted, thin and tender, with numerous oil sacs; usually depressed about the stem and at the stigmatic point; segments, 10 to 14, separating easily, with central pith open; flesh, dark orange; pulp sacs, short, broad, and blunt; juice, abundant; rag, scant; flavor, rich; quality, excellent; seed, 5 or more; cotyledons, plump, greenish hue. In Hawaii the fruit is in season during August and September.

Satsuma

The Satsuma has several synonymous names, as Oonshiu and Unshiu.

Fruit—Form, oblate; greatest diameter, 2¼ to 2¾ inches; base, full about the stem, with apex in shallow depression; rind, ⅛ inch thick, rather tough and irregular, sometimes furrowed about the stem, and ridged from stem toward apex, indicating outer curve of the pulp segments; oil cells, usually large and conspicuous; color, orange yellow; pulp segments, usually 13; core, little or none at full maturity, represented by a cavity about three-eighths inch in diameter; inner segments often separated; pulp, deep orange; juice sacs, short and plump; flavor, agreeable, rich, aromatic, with acidity and sweetness well balanced; quality, excellent; seeds, usually none to 1 to 4, plump, and top-shaped. The fruit is in season during late summer and early fall.

Willow-leaved

The Willow-leaved has several synonymous names, as China and Kid Glove.

Fruit—Size, small; form, oval-oblate, with base somewhat necked toward the stem and more or less ridged; stigmatic point in shallow depression; rind, yellow to orange, one-eighth inch thick, with irregular surface, and separates easily from the edible portion; oil cells, usually conspicuous; pulp sections, 10 to 13, well defined and varying in size; core, three-fourths inch in diameter, very spongy, contracting at full maturity, leaving a cavity; flesh, coarse-grained and of orange color; juice sacs, short and plump; juice, plentiful, with acidity and sweetness well combined; flavor, pleasing; seeds, 15 to 20, top-shaped, with inside of light green color. The fruit is in season during November and December.

King

The King mandarin, also called King of Siam and Scented, is in season during September and October.

Fruit—Form, oblate-roundish-ovate, often irregular; size, medium to large; greatest diameter, 2¾ to 3¼ inches; base, either depressed, or somewhat drawn out and contracted or grooved, with the stigmatic point usually depressed; rind, moderately thick, rather soft, with a distinctive aroma, and separates easily from the flesh segments, but less so than does that of the Dancy variety; segments, 10 to 13, loosely attached, forming an open, pithy center; pulp sacs, large, juicy; flavor, sweet and rich; seed, 10 to 20, plump, with light-green cotyledons.

Cleopatra

This tree is very ornamental and the seedlings make a good rootstock. The fruit is rarely eaten. The variety was first introduced into Florida from Jamaica and was brought to Hawaii that the rootstocks might prove useful in citrus propagation.

Fruit—Form, oblate, flattened, and irregular in outline; greatest diameter about 1¼ inches; color, dark orange red; oil cells of rind small and numerous; flesh, orange-colored, coarse-grained; usually about 20 seeds.

VARIETIES OF POMELOS[3] AND SHADDOCKS

Pomelos, shaddocks, and grapefruit are native to parts of Malaya and the East Indian Islands. Their cultivation has now extended to the frostless parts of many countries. The pomelo, like several other kinds of citrus, is evidently of early introduction into Hawaii. Hillebrand (*17, p. 77*), whose observations in Hawaii were made before 1871, stated that *Citrus decumana* has been so long in cultivation as almost to claim a place in the flora

[3] The name "pomelo," possibly a contraction of the Dutch "pompelmoes" (*3, v. 5, p. 2857*), is now recognized by all horticultural writers.

of the islands. In most American countries the species is divided horticulturally into two types or strains commonly identified as shaddocks and grapefruits.

Several grafted trees of the Siamese pomelo and a half dozen new hybrids of Siamese varieties with other citrus were received in 1930 by the station from the United States Department of Agriculture, Washington, D.C. Two of these have been set at the Kona substation, and the rest at the central station in Honolulu, where their development is being observed with considerable interest.

The tree (*Citrus decumana*) is vigorous, round-topped, and 15 to 30 feet high; the bark is thick and of brownish or grayish color, with small more or less spiny branches; the young growth is somewhat angular, but later becomes cylindrical and is usually glaborous; the leaves are large and coarse, 5 to 7 inches long, 2 to 4 inches broad; the leafstalk is ½ to 1½ inches long, marginal wings varying from mere ridges to ½ inch each (fig. 5, A); the blade is oval or elliptical-oval, entire or slightly irregular, scalloped or toothed; the apex is either acute or notched; the surface is dark green above, and lighter green below; the flowers are solitary, or in two to ten-flowered racemes from the axils of leaves; the individual flowers are large and fragrant; the calyx is cupular and clefted into 3 to 5 segments; the petals are 4 to 6, ovate-oblong, and white; the stamens are 20 to 35, each terminating with a large yellow anther; the pistil is globose, the style is columnar, the stigma is broad and globose and of yellow color.

Fruit—Size, 5 to 9 inches in diameter; form, globose, oblate, spherical or broadly pear-shaped, base, depressed or protruding about the stem attachment; apex or stigmatic portion, depressed; color at full maturity, light yellow, and in some varieties pinkish on portion exposed to sun; surface, densely studded with greenish glandular dots; rind, ½ to ¾ inch thick, pithylike, soft, and white; carpels or fruit sections, 11 to 21; pulp sacs, large and tapering, varying from dry to very juicy, and also from sweet to bitter. (In shaddocks the pulp sacs separate freely). Seeds vary from none to 120, and also in size and shape, being usually flattened and wrinkled.

Victoria

The Victoria was introduced into Hawaii about 1890 from Malaya and propagated by inarching and by grafting. Seedlings have occasionally given variations. The varietal name, "Victoria," was given to vegetatively-propagated plants some years ago by the owner, Mrs. V. Ward, "Old Plantation," 959 South King Street, Honolulu. The station received propagating material of the variety in November, 1922. Most of the varietal characters, other than those noted in the general description of *Citrus decumana*, exist in the fruit.

The tree rarely attains a height of 20 feet, is spreading and of dark brownish color; the branches are small and rarely spiny; the growth is first angular and later cylindrical, smooth, and dark green; the leaves are large, 5 to 7 inches long and 2 to 4 inches broad; the petioles are short, the marginal wings varying from mere ridges to ½ inch in width; the blade is ovate, oblong, or elliptical; the margins are entire or slightly serrated; and the apex is pointed or notched. The flowers are solitary, or in 2 to 10-flowered racemes in axils of leaves, and sometimes terminal on leafy branches; the individual flowers are large and fragrant; the calyx is cupular and slightly clefted into several greenish segments; the petals, 4 to 6, and occasionally more, are ovate-oblong and white; the stamens, 25 to 35, are white; the anthers are orange; the pistil is globose and yellowish green; the stigma is semi-globose.

Fruit—Size, 7 to 9 inches in diameter; form, oblate or globose, base either depressed or protruding about stem attachment; stigmatic end flattened or depressed; color, light yellow, often tinted pink on part facing the sun; entire surface, densely studded with greenish dots; rind, ½ to ¾ inch thick, inner part white and pithy; pulp sacs, 11 to 16, tapering to spindle shaped, adhering, of pale red to crimson color, juicy and sweet. The fruit varies from seedless to very seedy, depending on the season.

Quintal

The original tree of the Quintal was a seedling presumably of the Victoria, which it resembles in many characteristics and habits, and was grown by J. M. Quintal, 1522 Alexander Street, Honolulu. In December, 1922, the station obtained some of the graft wood for propagation and distribution.

Fruit—Form, globose; diameter 6 to 7 inches; surface, rather rough, pale greenish yellow at maturity; rind, ¾ to 1⅛ inch thick; carpels, about 14; pulp sacs, short, plump, spindle-shaped, juicy, pinkish, with slightly bitter tang but pleasing flavor; seeds, few, occasionally none.

Gehring

The original tree of the Gehring was a seedling grown by H. A. Gehring, 809 Kinau Street, Honolulu. The station began the vegetative propagation of the tree as a variety in 1921. The original tree was known as a shaddock, and the variety was recorded as accession No. 4545, and commonly designated as sweet shaddock. Other more or less sweet-fruited seedling shaddocks began to appear and the variety was called the Gehring. Because the fruit lacks coarseness and bitter tang, characters commonly determining most shaddocks in Hawaii, the Gehring is here described as of the pomelo strain.

Fruit—Form, globose, 6½ to 8 inches in diameter; surface, slightly rough or bumpy, greenish yellow; rind, ½ to ¾ inch thick; fruit sections, 15 to 19; pulp, yellowish green; sacs, numerous, slim, usually adhering; juicy seeds comparatively small, few to many varying with the season. The Gehring is an excellent breakfast fruit.

Carter

The original tree of the Carter was a seedling grown by the late Geo. R. Carter, Liliha Street, Honolulu. From graft wood, obtained by the station in September, 1922, fairly vigorous trees have been grown, but they are rarely prolific. The young twigs have a slight silvery pubescence.

Fruit—Size, large; diameter, 7 to 9 inches; form, globate or globose; surface, greenish yellow to yellow, comparatively smooth; rind, ½ to ⅞ inch thick; fruit sections, 12 to 16; pulp sacs, broadly spindle shaped, coarse, separating freely, and yellow; flavor, slightly bitter, but pleasing. The seeds vary from few to many.

Bitter

Trees of this seedling variety are large and prolific. The foliage is coarse and dark green. Although ornamental, the fruit is too bitter to be eaten, but the seeds are often used in producing rootstocks on which to graft other varieties of citrus.

Fruit—Size, large 5 to 7 inches in diameter; form, spherical; surface smooth, greenish yellow; rind, comparatively thin; seedy; pulp sacs, large, yellowish; juice, very bitter.

Tantalus

The original tree, apparently a seedling, is growing at the Tantalus substation. It is not known from where the plant was obtained or when it was planted. It is known, however, to be over 30 years old. In comparison with other shaddocks, it is small, has a round dense top and dark green foliage. Although it is not considered prolific, it usually has a fair crop of fruit.

Fruit—Size, large; form, oblate, about 6 inches in diameter; surface, rough, light green, studded with numerous large oil glands; stigmatic portion depressed often in the narrow slot about an inch long; pulp cells large, rather dry and rather bitter; numerous seeds.

Pyriform or Chinese

This variety is grown for its fruit which is used for its decorative effect and as a holiday delicacy. The true variety has been propagated vegetatively by air-layering for possibly a century. The fruit of seedlings tends to be more or less of a bitter flavor.

Fruit—Size, large; form, oblate to pyriform, 6 to 8 inches in diameter; surface greenish yellow, quite rough, and containing numerous large oil glands; rind, thick and spongy; pulp sacs, large, moderately juicy and of mild flavor; seeds varying from few to many.

Kohala

Possibly a variety originating as a seedling in Kohala, Ha-

waii. The true variety has been propagated by inarching and grafting. The trees are prolific and the fruit of excellent quality.

Fruit—Size, large; form, pyriform and often as much as 10 inches long; rind, thick and spongy; surface, pale yellow and dotted with numerous oil glands; pulp cells, large, pale yellow; seeds, few; flesh, moderately juicy and of very good flavor.

Seedless Pomelos

The seedless fruits of some varieties of pomelos are the most desirable. Seedlessness is restricted mainly to the spring crop, most of which matures about April. The blossoming time of the seedless crop ranges from the previous five to seven months when only very few other citrus trees are in bloom. Some varieties of pomelos are inclined to be everbearing, but all tend to have a main crop which, in Hawaii, matures in the fall and is usually seed-containing. The blossoms for the main crop come on in the early spring when most other kinds of citrus also are in bloom. The original tree of the Victoria variety of pomelo at the "Old Plantation," 949 South King Street, Honolulu, produces seedless fruit in the spring, and later fruit with seeds varying from few to many. The only citrus near this variety are two orange trees, which are within 150 feet. Seed production in the pomelo appears to be the result of fertilization from the pollen of orange flowers.

At the Hawaii station five young, grafted Victoria pomelo trees have fruited in season for 6 years. Three of them are in the citrus orchard of oranges, mandarins, grapefruits, limes, and lemons. The other two occupy large, individual tubs. The trees in the orchard produce fruit in the spring and in the fall. The early crop is seedless, or may contain some seed, whereas the fall crop usually contains 50 to 70 seeds per fruit, which approaches the maximum number. The blossoms producing the seedless fruit come on in the fall when few, if any, other citrus are in bloom except possibly the lemon. The trees in the tubs were kept with other kinds of pot-grown trees about 360 feet from the orchard and out of the current of the prevailing trade winds. They produced seedless fruit even at the time the same variety in the orchard bore seed-containing fruit. The flowers of the Victoria pomelo are believed to be self-sterile and to require pollination from other congenial citrus to produce seed-containing fruit.

Groff, in Siam (*14*), who, presumably from lack of time, was unable to prove that any one variety is absolutely seedless, found an approach to such a condition and reported trees bearing seedless fruit except on branches extending toward other varieties of regular seed-producing habits.

Fertilization of the ovules of the flower through pollination is essential to the setting and development of fruits, except in the case of edible bananas, Sultanina grapes, Oriental persimmons, and navel oranges. Coit and Hodgson (*8, p. 284, 293*) state that the blossoms of the Washington Navel orange are devoid of viable pollen, and that the variety has other characters indicating hybrid origin, but will set some seed if the ovules having normal embryo sacs are fertilized with pollen from some con-

genial variety. However, the possibility is usually rare, because many of the embryo sacs fail to develop.

In commercial orchards in California, the rarity of congenial varieties capable of fertilizing the flowers of navel oranges is evinced by the small percentage of seeds in the fruits, even when grown at no great distance from lemons and Valencia oranges. Assuming the congenial variety to belong to the same species, the Valencia orange may be concluded to furnish the pollen naturally fertilizing the flowers of navel varieties. The pollen of the Valencia, a variety of few seeds, is likely low in fertilizing power, which fact may influence the setting of few seeds in the navel variety. Results have been different at the Hawaii station. During the past 10 years several crops of navel oranges with abundance of seeds have developed. The orchard is a mixed planting of a number of species and varieties of citrus. Condition for pollination were unusually favorable at certain times. Although any of a number of citrus might have produced the pollen, the Hawaiian orange (fig. 3) is thought to be the congenial variety causing the navel orange and the Victoria pomelo to produce large numbers of seeds. The Hawaiian orange is known to have been propagated almost entirely by seeds for 140 years and to have strong seed-producing habits.

After carefully studying citrus species in southern Asia, Bonavia (*6, p. 37-38*) concluded that the pomelo is most closely allied to the Malta sweet orange. His conclusion was based on the following conspicuous characters, common to both: the pomelo and the sweet orange are the only two citrus species having varieties with reddish pulp; great similarity is seen in the leaves, both having winged petioles, in the emarginations of the base of the pulp carpels of the fruit, and in an occasional navel form of fruit (fig. 1, A, pomelo on the right with navel in stigmatic part).

At the station investigation is under way to ascertain the possibilities of producing regular seedless crops of both the Victoria and the Siamese varieties of pomelo. Isolated plantings have been made and experimental pollinations planned to determine definitely what species or varieties are congenial and whether the pomelos are absolutely self-sterile.

VARIETIES OF GRAPEFRUIT

Grapefruit propagating material was first obtained by the Hawaii station from Florida in 1906. From this material, trees of budded varieties were developed and set in orchard form in 1909, 1910, and 1911. The stocks used were sweet orange, grapefruit, sour orange, and rough lemon. Conditions in the orchard have not always been entirely favorable during the 22 years of its existence. Probably the most serious drawback to good culture has been insufficient moisture for considerable periods during several dry seasons. An improved water supply in recent years has largely overcome this difficulty, but the nature of the soil and the arrangement of the trees do not permit the proper application of water for best cultural results, particularly for control of the so-called gum diseases. The experiments have

given considerable information on methods of propagation, cultivation, irrigation, and pruning, use of fertilizers and of cover crops, season of fruiting, and yields, pollination and seed-producing habits, varietal studies under Hawaiian conditions, and insect and plant-disease control. It has also furnished abundance of material for propagation experiments and cooperative experiments with interested growers in many parts of the Territory.

Triumph

The original tree of the Triumph grew in the grounds of the Orange Grove Hotel, Tampa, Florida. As a variety it has been propagated vegetatively since 1884. Trees of the variety growing at the station were propagated from bud wood obtained from Florida in 1906.

Fruit—Form, globose to oblate, slightly flattened at base and apex; greatest diameter, 3¾ to 4 inches; stem, small; color, light yellow; rind, ⅛ to ¾ inch thick; surface, smooth; oil cells, comparatively large; sections, 11; pulp sacs, coarse, juicy, and of pleasing flavor; seeds, 30 to 40, rather small and partly winged.

Marsh

The original tree of the Marsh or the Marsh Seedless was a seedling growing at Lakeland, Florida, whence it was introduced as a variety by C. M. Marsh about 1896. The fruit is particularly desirable on acount of its good quality and comparatively seedless habit. The variety was introduced into Hawaii by the station in 1906.

Fruit—Form, oblate to roundish; greatest diameter, 3½ to 4½ inches; stem, small; light yellow; rind, ⅛ to 3/16 inch thick; surface, smooth; oil cells, small; sections, 11 to 13; pulp sacs, grayish green, small, and juicy; acidity, medium, with slight trace of bitter principle; central pith often open; usually seedless, seed when present varying from 1 to 6, short and plump.

Royal

The original tree of the Royal was introduced into Florida from Cuba about 1875. It was propagated vegetatively and in 1891 was named as a variety by the late E. N. Reasoner, of Oneco, Florida. The Royal was introduced into Hawaii by the station in 1906.

Fruit—Form, globose to slightly oblate; greatest diameter, about 3¾ inches; stem, stout; rind, light yellow, ⅛ inch thick; oil cells, small; sections, 10 to 12; pulp sacs, gray-green, juicy; flavor, good, the acidity and sweetness blending well and the bitter principle is almost lacking; seeds, 40, of medium size.

Duncan

The Duncan, a variety of unusually good quality, was originated by A. L. Duncan, of Dunedin, Florida. Propagating material of the variety was obtained by the Hawaii station in 1906. It fruits well under Hawaiian conditions and the fruit averages large.

Fruit—Form, oblate or globose; greatest diameter, 4 to 4¾ inches; stem, stout; apex, slightly scarred; rind, ⅛ to 3/16 inch thick; oil cells, numerous and sunken; surface, greenish yellow; sections, 12 to 14; juice sacs, large, closely packed, light grayish green; flavor, good, with acidity and sweetness blended; bitter principle well marked; seeds, about 40, varying in size and in shape.

Imperial

In Hawaii the Imperial is sometimes called the Whitney Imperial. The trees are said to be vigorous and prolific. Those at the station have suffered badly from gum disease, but tend to bear abundant fruit of good quality. Bud wood of the variety

was introduced at the station from California in 1906, but the trees from this source soon died and new material was obtained from the late J. M. Whitney, of Honolulu.

Fruit—Form, globate to oblate; greatest diameter, 4 to 4½ inches; stem, stout; rind, 3/16 inch thick; surface, smooth; oil cells, small and of yellow color; sections, 11 to 14; pulp sacs, small, numerous and juicy; flavor, a pleasing blend of acid sweetness and bitter principle; seeds, 60 to 80, with wrinkled coat usually extending into a broad wedge-shaped wing.

Foster

The Foster is a comparatively new and early variety that has become a favorite with many growers. The original tree was a sport of the Walters which it closely resembles except that the Foster has pink flesh. Graft wood was introduced at the station from Florida about 1910, but the trees from it died and in 1926 a new supply was obtained from the late E. N. Reasoner, from which a tree was set in the station orchard in 1928.

Fruit—Form, oblate; greatest diameter, 4¼ inches; stem, small; rind, smooth, pale yellow, ¼ inch thick; sections, 12 or 13; pulp sacs, of medium size, purplish pink, often deepest in color next to the rind, shading to translucent near the core; acidity and sweetness good, bitter principle strongly marked; seeds, 40 to 80, plump with seed coat flattening into a wedge.

Pernambuco

The Pernambuco (fig. 4, B) was introduced into the United States from Pernambuco, Brazil, through the United States Department of Agriculture. Bud wood was obtained by the Hawaii station in 1909 and the first trees were set in 1910-11. The fruit matures from September to January.

Fruit—Form, oblate or ovate; greatest diameter, 4 to 4½ inches; stem, stout; rind, smooth, light greenish yellow; oil cells, medium, sunken, ¼ inch thick; sections, 12; pulp sacs, coarse, gray green; acidity and sweetness, good; bitter principle rather strongly marked; seeds, 60 to 80, plump and wedge-shaped.

Tresca

The original tree of the Tresca was a seedling grown by Fred Tresca in Florida about 1887 from seeds obtained from the Bahamas. Through vegetative methods of propagation the variety was established and named by the late E. N. Reasoner.

Fruit—Form, globate to pyriform; greatest diameter, 4½ inches; color, dark lemon-yellow; apex, broad, flat, and usually scarred; base, ridged and usually roughened; rind, ½ to ¾ inch thick; oil cells vary in size, with large ones sunken; sections, 14 or 15, irregular in size; pulp sacs, large and irregular, pinkish, juicy, with acid sweetness and bitter principle well blended; seeds, about 70, pinkish, small, and wedge-shaped.

Woodworth

The Woodworth was obtained by the Hawaii station from Florida in 1906. This little known variety compares favorably with other varieties grown in Hawaii.

Fruit—Form, oblate; greatest diameter, 4¼ inches; rind, smooth, orange color, 3/16 inch thick; oil cells, small, numerous, with a few sunken; sections, 11 or 12; juice sacs, small, break upon being separated; acidity and sweetness are well blended and the bitter principle is marked; seeds, about 45, small, varying in size.

Seedling No. 1557

Seedling No. 1557 was grown from grapefruit introduced from California in 1905. It is vigorous upright and prolific. The fruit is attractive and compares favorably with that of established varieties.

Fruit—Form, globate or oblate; greatest diameter, 4 to 4½ inches; apex, sunken; rind, ¼ inch thick; surface, rough; oil cells, pitted; color, yellow; sections, 11 or 12; pulp sacs, of medium size, adhering; juice, acid and bitter principle well marked; seeds, about 75, small, plump, and with short wedge-shaped wing.

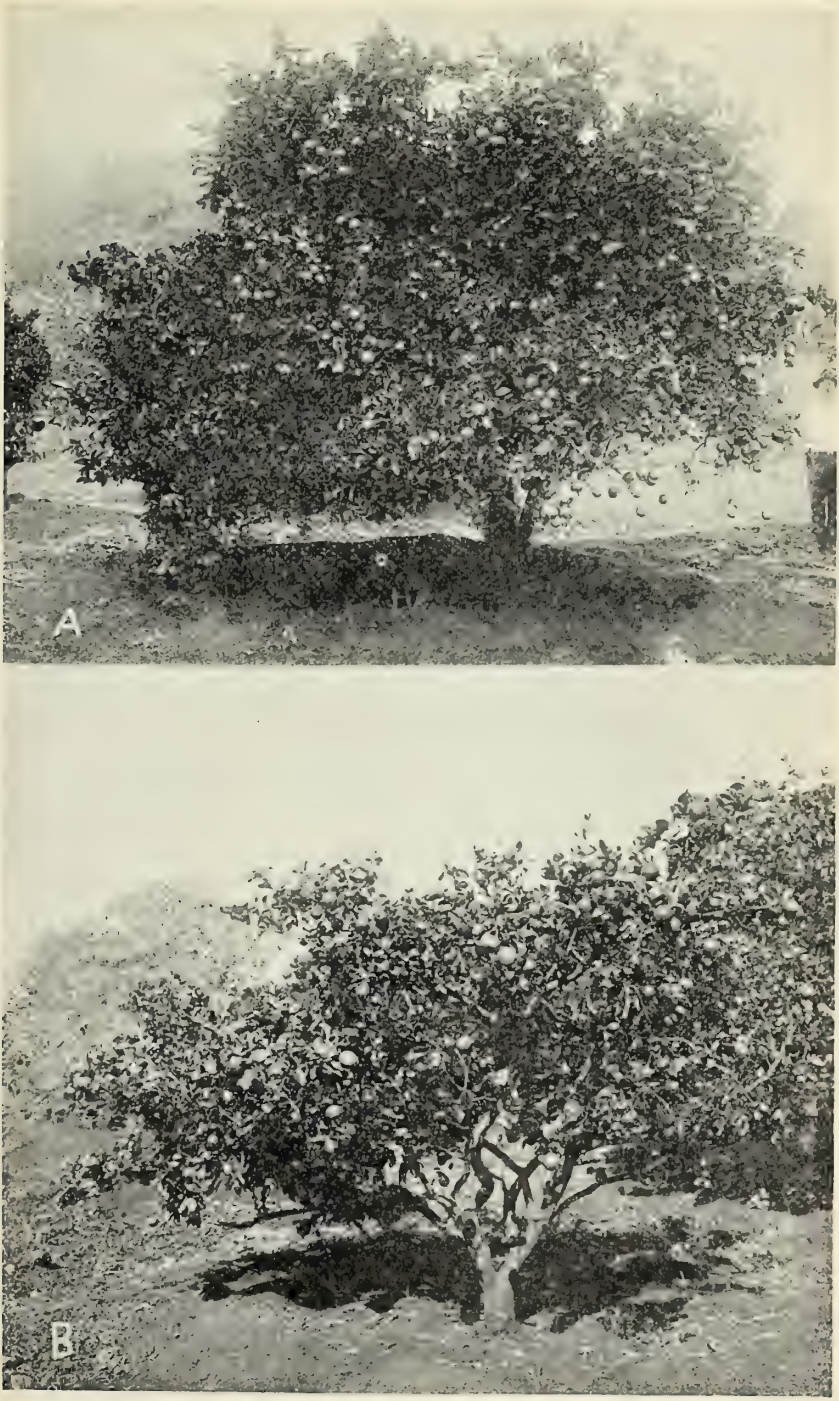

Figure 5.—Lemon trees. A, The Rough lemon. This is the most prolific and disease-resistant lemon at the station. B, A grafted Eureka lemon tree dwarfed by pruning and development.

VARIETIES OF LEMONS

The lemon is native of tropical and subtropical Asia, but is now cultivated in many warm parts of the world, and was introduced into America by Spanish settlers. In Florida the varieties Everbearing and Rough have some commercial value. Lemon growing has spread to several of the southern States, including California. The exact date of its introduction into Hawaii is not known, but the fruit is said to have been in cultivation here during the early part of the nineteenth century. European and Californian varieties have been introduced into Hawaii from the United States. The station has obtained graft wood of the varieties Sicily, Lisbon, Villafranca, Rough, Eureka, Ponderosa, American Wonder, and Sweet. The trees are easily identified by the odor of their leaves when crushed. The leafstalks also differ from those of other forms of citrus in being wingless.

Rough

The Rough variety (fig. 5, A) is the most resistant and prolific of the lemon varieties in Hawaii. Although somewhat thorny, the Rough lemon is a splendid dooryard tree. Several trees have been developed from a rootstock that sprouted after the scion of some other citrus had died back.

Fruit—Form, oblong, ovate or roundish; size, medium to large with blunt base, sometimes elevated so as to surround the calyx; rind, decidedly rough; pulp sections, 9 to 12, well defined, open pith in center; pulp, yellow, sacs large; juice, abundant, clear; acid, medium, agreeable; seeds, few, small, and plump.

Eureka

The Eureka (fig. 5, B) was introduced into Hawaii in 1906 from Los Angeles, California, where the variety originated. The station produced a number of trees from the first propagating material for distribution to cooperative growers and for trial in the station orchard. The station trees were heavy bearers when young but were later attacked by gummosis. The variety should be grafted rather high on sour orange stock and grown in soil having good underdrainage.

Fruit—Size, medium; form, oblong with tapering base; apex, nippled; rind, smooth, glossy; juice, abundant, clear, strong acid; flavor, good; seeds, none to few.

Villafranca

The Villafranca was introduced into Hawaii for the first time from California in 1906. The trees are prolific, almost thornless, and on sour orange stock are resistant to gummosis.

Fruit—Size, medium; form, oval-oblong with rounded base and bluntly pointed apex; rind, smooth and thin; juice, clear, strong, with good flavor; seeds, few to about a dozen.

Lisbon

The Lisbon was introduced into Hawaii in 1906, but the trees did not do well at the station. The tree is reported to be vigorous and productive, but thorny.

Fruit—Size, large; form, oblong with bluntly pointed base, sometimes necked; apex, distinctly nippled; rind, fairly smooth, thin; pulp sections 10 or 11; juice, clear, acid, strong; seeds, few, usually abortive.

Sicily

A grafted tree of the Sicily was obtained locally by the sta-

tion in 1906 but died some years later. Since that time the variety has not been observed in cultivation in Hawaii.

Fruit—Size, large; form, oblong with rounded base; apex, abrupt nipple; rind, thick, slightly rough; flesh, fine-grained; juice sacs, small; juice, acid, abundant, and clear; flavor good; seeds, about 12.

Ponderosa

The Ponderosa produces fruit 4 to 6 inches long. The leaf stalks are more or less winged, indicating a possible close relationship to the pomelo or grapefruit. The variety, on account of the size of the fruit, is not suited for commercial production.

Fruit—Form, oblong, pyriform, sometimes distinctly necked, 4 to 6 inches long; lemon yellow, coarse rind, often raised about stem attachment; apex, roundish and slightly nippled; rind, rough, ½ inch thick; oil cells, large; fruit sections, 12; flesh, grayish and coarse-grained; pulp sacs, large and juicy; flavor, strongly acid but agreeable; seeds, about 20, oval to wedge-shaped.

American Wonder

The tree and the fruit of the American Wonder are similar to those of the Ponderosa of which it is probably a variation. The variety was first introduced from California. It differs from the Ponderosa in having a part of the fruit spherical, whereas the rest are lemon-shaped.

Fruit—Form, spherical or oblong; stigmatic point either a mere speck on the surface, or extended into an acute lemonlike beak; surface, comparatively smooth, greenish yellow; rind, ¼ inch thick; pulp, greenish gray, juicy; acid, strong; flavor, not exactly like that of the lemon.

VARIETIES OF LIMES

The acid lime is found in cultivation in many tropical countries. Its native country is believed to be in some part of southern Asia. The species in general is easily naturalized and spreads by seeds and by root sprouts. Through long periods of cultivation of the tree the thorns have been reduced in size and in number, and the fruit has been improved. Because of its easy culture and early habit of bearing, the tree is well adapted to growth in home gardens. Lime juice is used in the preparation of beverages, for seasoning fish and meat, and to improve the palatability of many other kinds of food. Acid lime fruits in cultivation in Hawaii are the Kusaie, West Indian, Rangpur, and Tahiti (*21*).

Kusaie

The Kusaie was introduced into Hawaii from the island of Kusaie in Micronesia in 1885. It soon gained in favor, due to its easy culture and prolificacy. When propagated from seeds the variety is slightly variable, but a good standard variety may be established by grafting.

The trees vary in size from mere bushes to well-formed evergreens 8 to 10 feet high. The foliage is dense, the leaves are small, and the twigs armed with a few small thorns. The trees often come into bearing during the second year and continue to produce almost throughout the year.

Fruit—Form, oval, spherical, or oblate, the diameter rangign from 1¾ to 2½ inches; rind, yellow, thin; oil cells, numerous; pulp segments, 6 to 10; flesh, clear honey-yellow color; juice, abundant and with a characteristic flavor; central pith, usually open; seeds, plump and few in number.

Rangpur

The Rangpur, also known as Rungpur or Rungpor, originated in India. All its characters are not those of a true lime. The color of the fruit, the ease with which the peel separates from

the pulp, and the peculiar flavor are characters indicating relationship to the mandarin group. The variety probably reached Hawaii from Florida.

The tree is small and of spreading habit. The branches are thorny, the foliage is rather sparse, and the leaves have rounded apexes.

Fruit—Matures in the fall and the early winter. Form, round, oblate, tending toward ovate, occasionally necked; greatest diameter, 2 to 2½ inches; rind, rough, orange red; segments 7 or 8; flesh, coarse, orange colored; juice, plentiful with agreeable flavor; central pith, small and open; seeds, plump, 7 to 18, of greenish color in side.

West Indian

The West Indian, also called the Mexican, is grown extensively in the West Indies, Florida, and Mexico.

The trees are short-lived in Hawaii. They remain shrubby, rarely attaining a height of 10 feet. The twigs are well provided with small, sharp thorns, and with light-green foliage.

Fruit—Form, oval to oblong; the greatest diameter, 1¾ to 2½ inches; rind, firm, smooth, thin and yellow; flesh, fine-grained and of green color; juice, plentiful and translucent; acid, very strong, the flavor being distinctly of the lime, central pith, open and small; seeds, few to many, wedge-shaped to pointed.

Tahiti

The Tahiti is supposed to be a mutation of the Persian variety of lime.

The tree attains a height of 15 feet and forms a dense mass of foliage. The leaves resemble those of the lemon. The maturing season of the fruit is during early fall to December. The tree is of easy culture and tends to be prolific.

Fruit—Form, oblong; the greatest diameter, 2½ to 3¼ inches; rind, smooth, firm, and green; flesh, fine grained and green; segments, usually 10; juice, plentiful, almost colorless and strongly acid in flavor; central pith, open and small; seedless.

SUMMARY

Hawaii is adapted to the growing of all kinds of citrus, and at one time exported oranges to a considerable extent. The industry began to decline previous to 1870 as a result of the development of the more remunerative coffee, sugar, and livestock industries. The Mediterranean fruit fly is the most serious obstacle to successful growing in Hawaii, but this pest has been brought under partial control by the use of parasitic insect enemies.

Seed in the navel orange, Victoria pomelo, and Marsh grapefruit, which normally are seedless, was observed when nearby seed-producing sweet oranges, pomelos, and grapefruit were in blossom at the same time. Isolated trees of seedless varieties have borne large crops of seedless fruit, a fact that confirms the findings in other investigations and indicates that seedlessness is due to lack of pollination.

The results of investigations by Bonavia (*6*), indicating that pomelos, and all kinds of *Citrus decumana* are more closely related to oranges than to any other citrus species, have been verified by observations at the station. Both oranges and pomelos were found to be less likely to produce seedy fruit when light showers at blossoming time were frequent enough to keep citrus pollen heavy with moisture, and to prevent pollen-carrying insects from working among the flowers.

In Hawaii citrus varieties are vegetatively propagated best by grafting the desired scions on either shaddocks or sour orange stock. The most successful have been side-bark unions in which scions of the current year were united with 10-month old seed-

lings growing in 8-inch containers. Emphasis has been placed on the importance of drying citrus seeds only slightly between the time of removal from the fruit and planting to prevent "bench root" conditions. Experiments by the station showed sour orange stock to be resistant to gummosis, and shaddock stock to be unusually vigorous. If the stocks are planted rather high in the tree hole so that eventually the crown roots will be slightly exposed above the general surface of the ground, attacks of gummosis will be rare. In irrigation it is highly important that the soil should not be allowed to become waterlogged or sour as such conditions are not only very favorable to the spread of gummosis but may kill the trees.

The pruning of citrus trees is most important during the early training and formation of the crown branches supporting the top. Severe pruning should be avoided as it will upset steady growth much as does improper fertilizing.

Cover crops should be grown in the orchard and turned under once, or, in many cases, twice a year. Hawaiian soils are generally lacking in organic matter and when used for orchard purposes should be enriched and given greater moisture-holding capacity. The improved physical condition greatly aids the beneficial action of bacteria.

Citrus fruits can be successfully matured in individual bags of paper or of cellophane. These should be placed over the fruit 4 or 5 weeks before it is mature enough to turn yellow.

Both parasitic insects and strong juices of the rind usually prevent fruitfly eggs from hatching or the young larvae from developing on the fruit. Punctures made by adult flies in depositing the eggs invariably cause the fruit to fall in the early stages of ripening. Fruit punctured by the fly is more subject to decay, and consequently is unsuited for packing for shipment.

LITERATURE CITED

(1) Back, E. A., and Pemberton, C. E.
1915. susceptibility of citrus fruits to the attack of the mediterranean fruit fly. Jour. Agr. Research 3:311-330, illus.

(2) ———
1918. the mediterranean fruit fly in hawaii. U. S. Dept. Agr. Bul. 536, 119 p., illus.

(3) Bailey, L. H.
1916. the standard cyclopedia of horticulture. Ed. 2. 6 v., illus. New York and London.

(4) ——— and Bailey, E. Z.
1930. hortus, 652 p., illus. New York.

(5) Barger, W. R., and Hawkins, L. A.
1926. coloring citrus fruit in florida. U. S. Dept. Agr. Dept. Bul. 1367, 20 p., illus.

(6) Bonavia, E.
1890. the cultivated oranges and lemons (etc.) of india and ceylon. 384 p. London.

(7) Coit, J. E.
1915. citrus fruits. 520 p., illus. New York.

(8) ——— and Hodgson, R. W.
1919. an investigation of the abnormal shedding of young fruits of the washington navel orange. Univ. of Calif. Publications in Agr. Sciences 3:283-368, illus.

(9) Ehrhorn, E. M.
1912. mediterranean fruit-fly. (ceratitis capitata) wiedemann. Hawaii Bd. Agr. and Forestry, Div. Entomology Circ. 3, 7 p., illus.

(10) Essig, E. O.
1915. injurious and beneficial insects of california. Calif. State Com. of Hort. (Supplement to the monthly bulletin of the State Commission of Horticulture). 4:541 p., illus. Ed. 2.

(11) Fawcett, H. S., and Lee, H. A.
1926. citrus diseases and their control. Ed. 1, 582 p., illus. New York and London.

(12) Fortier, S.
1917. irrigation of orchards. U. S. Dept. Agr. Farmers' Bul. 882, 40 p., illus.

(13) Galloway, B. T.
1924. how to collect, label, and pack living plant material for long-distance shipment. U. S. Dept. Agr. Dept. Circ. 323, 12 p., illus.

(14) Groff, G. W.
1927. culture and varieties of siamese pummelos as related to introductions into other countries. Lingnan Science Jour. (Lingnan Agrl. Review) 5:187-254, illus. Lingnan Univ., Canton, China.

(15) Henricksen, H. C.
1930. citrus culture in porto rico. Porto Rico Agr. Expt. Sta. Bul. 33, 34 p., illus.

(16) Higgins, J. E.
1905. citrus fruits in hawaii. Hawaii Agr. Expt. Sta. Bul. 9, 31 p., illus.

(17) Hillebrand, W.
1888. flora of the hawaiian islands. 673 p., illus. New York, London, and Heidelberg.

(18) Hume, H. H.
1904. citrus fruits and their culture. 597 p., illus. Florida.

(19) JOHNSON, M. O., THOMPSON, A. R., and SAHR, C. A.
1917. COMPARATIVE VALUE OF LEGUMES AS GREEN MANURES. Hawaii Agr. Expt. Sta. Press Bul. 52, 15 p., illus.

(20) PIPER, C. V., and PIETERS, A. J.
1922. GREEN MANURING. U. S. Dept. Agr. Farmers' Bul. 1250, 46 p., illus.

(21) POPE, W. T.
1922. THE ACID LIME FRUIT IN HAWAII. Hawaii Agr. Expt. Sta. Bul. 49, 20 p., illus.

(22) RESTARICK, (BISHOP) H. B.
1931. HAWAIIAN AFFAIRS OF THE PAST. Article in Honolulu Star-Bulletin, February 21.

(23) RHOADS, A. S., and DEBUSK, E. F.
1931. DISEASES OF CITRUS IN FLORIDA. Univ. of Florida Agr. Expt. Sta. Bul. 229, 213 p., illus.

(24) SHAMEL, A. D., POMEROY, C. S., and CARYL, R. E.
1923. PRUNING CITRUS TREES IN THE SOUTHWEST. U. S. Dept. Agr. Farmers' Bul. 1333, 32 p., illus.

(25) SMITH, R. E., and SMITH, E. H.
1911. CALIFORNIA PLANT DISEASES. Univ. of Calif. Expt. Sta. Bul. 218, p. 1039-1193, illus.

(26) TAYLOR, W. A.
1908. PROMISING NEW FRUITS. U. S. Dept. Agr. Yearbook, 1907: 305-320, illus.

(27) THOMAS, E. E.
1922. STUDIES ON THE IRRIGATION OF CITRUS GROVES. Univ. of Calif. Publications Bul. 341, p. 353-370.

(28) VANCOUVER, (CAPTAIN) G.
1798. A VOYAGE OF DISCOVERY TO THE NORTH PACIFIC OCEAN, AND ROUND THE WORLD. 3 v., illus. London.

(29) VOSBURY, E. D., and ROBINSON, T. R.
1927. CULTURE OF CITRUS FRUITS IN THE GULF STATES. U. S .Dept. Agr. Farmers' Bul. 1343. Revised. 42 p., illus.

(30) WILLARD, H. F.
1930. PARASITISM OF THE MEDITERRANEAN FRUIT FLY IN HAWAII, 1922-1924. U. S. Dept. Agr. Circ. 109. Corrected edition. 12 p.